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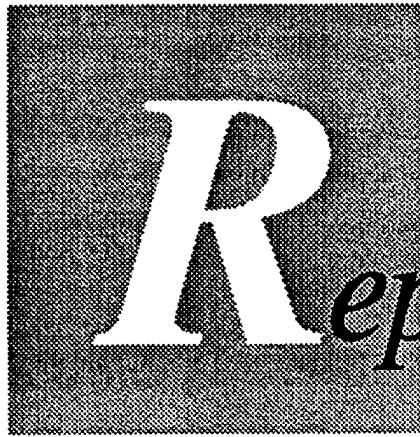
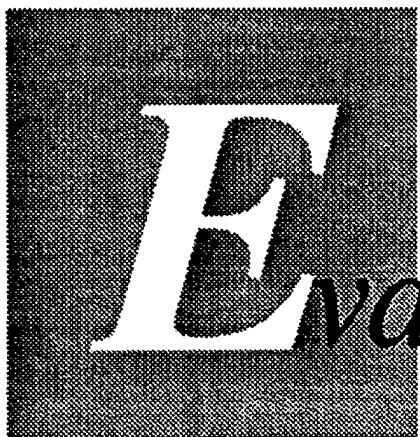
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Evaluation

Report



HELLFIRE MISSILE SYSTEM REMOTE CONTROL CIRCUIT
BREAKERS ON THE AH-64A APACHE ATTACK HELICOPTER

Report Number 98-101

APRIL 3, 1998

Office of the Inspector General
Department of Defense

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Acronyms

BIT	Built-in Test
FD/LS	Fault Detection/Location System
I/CU	Indicator/Control Unit
MDHS	McDonnell Douglas Helicopter Systems
RCCB	Remote Control Circuit Breaker
TI	Texas Instruments, Inc.



INSPECTOR GENERAL
DEPARTMENT OF DEFENSE
400 ARMY NAVY DRIVE
ARLINGTON, VIRGINIA 22202

April 3, 1998

MEMORANDUM FOR DIRECTOR, DEFENSE LOGISTICS AGENCY
AUDITOR GENERAL, DEPARTMENT OF THE ARMY

SUBJECT: Evaluation Report on the Hellfire Missile System Remote Control Circuit
Breakers on the AH-64A Apache Attack Helicopter
(Report No. 98-101)

We are providing this evaluation report for your information and use. Because this report contains no findings or recommendations, no written comments were required, and none were received. Therefore, we are publishing this report in final form.

We appreciate the courtesies extended to the technical assessment staff. Questions on the evaluation should be directed to Mr. Kenneth H. Stavenjord, Technical Director, at (703) 604-8952 (DSN 664-8952) or Mr. Jaime A. Bobbio, Evaluation Project Manager, at (703) 604-8915. See Appendix B for the report distribution. The evaluation team members are listed inside the back cover.

Robert J. Lieberman
Assistant Inspector General
for Auditing

Office of the Inspector General, DoD

Report No. 98-101
(Project No. 7PT-9028)

April 3, 1998

Evaluation on the Hellfire Missile System Remote Control Circuit Breakers on the AH-64A Apache Attack Helicopter

Executive Summary

Introduction. Remote control circuit breakers are trip-free thermal devices that combine the functions of a conventional circuit breaker and relay into one device. The remote control circuit breakers are used in the AH-64A Apache Attack Helicopter to prevent electric current overloads to the Hellfire Missile System. The Office of the Assistant Inspector General for Auditing performed a technical evaluation of the breakers based on a Hotline allegation that the breakers were defective in design and workmanship.

Evaluation Objectives. The evaluation objective was to conduct a technical assessment to determine the adequacy of the design, quality control, and acceptance of the remote control circuit breakers. Specifically, we evaluated and tested remote control circuit breakers for design and quality to ensure that the United States Army Aviation and Troop Command (now Army Aviation and Missile Command), McDonnell Douglas Helicopter Systems, and Texas Instruments complied with manufacturing and quality processes.

Evaluation Results. The allegation was not substantiated. The design, quality control processes, and operability for the Hellfire Missile remote control circuit breakers on the AH-64A Apache Attack Helicopters were satisfactory. Most of the circuit breaker failures were found in the initial 719 units manufactured on the pilot assembly line. Field test results revealed that the remote control circuit breakers in use were functioning properly. A 10-year usage history indicated that 380 circuit breakers have been issued to the field, compared to 4,685 units initially installed. Records and interviews of the maintenance personnel at various Army installations showed that the quality of the first 719 breakers manufactured by Texas Instruments on the pilot assembly line used on the first 144 AH-64A Apache Attack helicopters were satisfactory and reliable.

Management Comments. Because this report contains no findings or recommendations, written comments were not required, and no comments were received. Therefore, we are publishing this report in final form.

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Part I - Evaluation Results

Evaluation Background

On August 15, 1991, the United States Army Aviation Command issued an Aviation Safety Action Message (AH-64-91-ASAM-15) to alert military installations about miswiring in the missile system remote control circuit breakers (RCCBs) and urged a one-time inspection of RCCB wiring.

In January 1992, subsequent to the above aviation safety action message, six RCCBs were found defective at Fort Rucker during an inspection of AH-64A Apache Attack Helicopter missile circuitry. Fort Rucker prepared and forwarded a Quality Deficiency Report to McDonnell Helicopter System (MDHS). An analysis revealed that the Q3 transistor had failed in all six RCCBs. The root cause of the specific RCCB failures was not determined.

In November 1994, the Defense Criminal Investigative Service initiated an investigation based on a Hotline allegation that the circuit card assemblies used in the RCCBs on the AH-64A Apache Attack Helicopter were defective in design and workmanship. Defense Contract Management Center engineers opened and inspected three RCCBs from the original pilot assembly line and found workmanship defects. In January 1997, the allegation was referred by the Defense Criminal Investigative Service to the Office of the Assistant Inspector General for Auditing for a technical evaluation.

Evaluation Objectives

The primary objective was to conduct a technical evaluation to determine the adequacy of the design, quality control, and acceptance of the remote control circuit breakers. Specifically, we evaluated and tested RCCBs for design and quality to ensure that U.S. Army Aviation and Troop Command (now Army Aviation and Missile Command), McDonnell Helicopter System (MDHS), and Texas Instruments, Inc. (TI) complied with manufacturing and quality processes.

Remote Control Circuit Breakers Quality, Testing, and Design

The design, quality, and workmanship of the remote control circuit breakers are satisfactory. Field tests verified that all the RCCBs on four Apache Attack Helicopters inspected were operating properly. Also, records showed that only about 1 percent of RCCBs system-wide have been issued to the field over the last 10 years.

Quality

Texas Instruments, Inc. (TI), Attleboro, MA designed and developed 10RC RCCB as a commercial circuit breaker for wide industry use. In 1984, TI began shipping 10RC RCCBs for Apache helicopters to Hughes Helicopter Co. (now McDonnell Douglas Helicopter Systems [MDHS]). Per company policy, production and shipping records are maintained for 7 years minimum. However, TI provided the 11-year record of 4,272 units delivered to MDHS.

There were no TI RCCB shipment records for 1984 or 1985. Officials at TI stated that they inspected and tested 100 percent of all RCCB shipments to MDHS and provided a certificate of conformance with each batch of the devices. As of April 1997, approximately 54 RCCB failures have been reported to TI. Most of the 54 failures occurred in the initial 719 RCCBs built by TI on the pilot assembly line. Our evaluation focused on those initial 719 RCCBs that were used in the first 144 Apache helicopters manufactured by MDHS. Each Apache helicopter Hellfire Missile System uses five RCCBs.

The initial 719 units that were produced on the pilot assembly line were no different from the production (post 719 units) except that the former used TI built electronics modules while the latter used electronics modules purchased from various vendors.

Analysis by TI of the RCCBs returned by MDHS revealed deficiencies in the following categories: bias spring adjustment, shorted diodes, Q3 transistor breakdown, misassembled tantalum capacitor, and applications issues that included broken studs, damaged connector modules, Desert Storm sand ingestion, and product understanding.

Remote Control Circuit Breakers Quality, Testing, and Design

Deficiency explanations and corrective actions by TI are as follows:

- **Q3 transistor breakdown.** MDHS returned six RCCBs to TI in December 1991. The failure caused solenoid burnout resulting in subsequent loss of the device function. Another device failure was reported in 1992, but TI testing showed no device or component damage to the Q3 during normal device operation. TI did not determine the root cause of these failures. However, TI replaced all the failed units with new RCCBs.
- **Shorted blocking diodes.** MDHS returned five devices in 1990 for shorted blocking diodes. The TI diode supplier analyzed and determined the cause of failure as arc-over the diode. The cause of the reverse voltage overstress in the diodes could not be determined. However, TI self-initiated a post-production test of the diode to ensure that it was functioning properly.
- **Misassembled capacitor.** In 1991, MDHS returned one RCCB because of failure to reset. TI analysis determined that the tantalum capacitor on the hybrid circuit had been assembled backwards by the supplier. The supplier instituted a double inspection process to insure that future capacitors are orientated correctly. Additionally, TI instituted a 100 percent x-ray inspection of the capacitors.
- **Bias Spring.** In 1984 and 1985, TI initiated a recall of all initial production devices to adjust the bias spring to minus 65 degrees Fahrenheit to improve the trip characteristics of the 10RC RCCB. The devices were readjusted and returned to MDHS.

On March 1, 1992, after six defective RCCBs were discovered at Fort Rucker, MDHS started testing RCCBs as part of their Point Target Weapon Subsystem (Hellfire Missile) testing. However, by July 22, 1991, MDHS had already built and sold 849 Apache Helicopters (equipped with 4,245 RCCBs) to the United States Army that were not included in the MDHS Point Target Weapon Subsystem testing.

Army policy for the past several years is to keep maintenance records for only 6 months. We reviewed maintenance records of 68 helicopters stationed at Fort Eustis, Fort Rucker, Fort Hood, and Corpus Christi Army Depot. We found 11 to 15 RCCBs had been replaced. Our discussions with Army and contractor maintenance personnel revealed only one RCCB was replaced at Fort Eustis and four at Fort Rucker during the past 2 years. Fort Hood maintenance personnel recalled that they replaced approximately 6 to 10 RCCBs during the past 11 years. Corpus Christi Army Depot did not keep records of the RCCB replacements because they are throwaway (expendable) items.

We concluded the quality of the RCCB was satisfactory. TI stated that they inspected RCCBs at each stage of the assembly operation and had only received approximately 54 defective RCCBs out of 4,710 manufactured by TI. The Defense Supply Center Columbus item manager reported on 380 units ordered over the last 10 years. This amounts to approximately a 1-percent usage rate. Army Apache helicopter stations reported only six Quality Deficiency Reports related to RCCBs failures. Maintenance records confirmed a very low RCCB usage rate. Many RCCBs produced on the pilot line were still operational. We visited four military facilities and found 68 Apache helicopters containing 340 RCCBs with 84 RCCBs from the pilot production of 1984 and 1985 still in operation. In addition, we opened and inspected a RCCB removed from an operational helicopter, RCCB serial number 419 from the original pilot assembly line, and found no workmanship defects.

Thus, on the basis of our review of records and interviews of maintenance personnel at the four Army installations and TI, we conclude that the quality of the first 719 RCCBs manufactured by TI on the pilot line was sound. The RCCBs are still providing highly reliable performance in the field.

Testing

Texas Instruments officials stated that the RCCBs are tested and inspected at each stage of pilot line assembly and they provided a certificate of conformance with each shipment sent to MDHS. After integration of the Hellfire Missile System with the Apache helicopter, MDHS performed a missile subsystem test of all five RCCBs on each helicopter using test set AN/TSN-205. We observed and verified TI testing on the current RCCB production line.

Additionally, the Apache helicopter/Hellfire Missile System is equipped with a set of built-in tests (BITs) for fault detection and location system (FD/LS) in the missile subsystem electric circuitry at individual missile pylon. A missile warning light on the cockpit panel blinks only if all four missile stations fail. Fault isolation up to pylon/station level can be detected by reading information displayed on the screen located in the cockpit. However, this test would not identify individual RCCB failure. Therefore, a BIT to check the circuit continuity in an individual RCCB is also performed in the helicopter cockpit. There are five pop-up switches, and a circuit breaker indicator/control unit (I/CU), one for each RCCB located on the left-hand side of the cockpit. If there is failure in an individual pylon/station circuitry including the RCCB, the pop-up switch would open and the display screen would indicate a failure in the circuit. When there is no fault in the RCCB circuit, the pop-up switch remains in the down (closed) position. When there is no anomaly in the circuit, the pop-up switch opens or closes the RCCB as designed. These BIT tests are performed before a mission begins.

Remote Control Circuit Breakers Quality, Testing, and Design

Most of the Apache helicopter field maintenance units are trained to use AN/TSN-205, Hellfire Guidance Test Set. This test set is capable of detecting and isolating faults to the lower replaceable units of the Hellfire missile circuit including the RCCBs.

We participated in the FD/LS and RCCB pop-up switch BITs at Fort Eustis, Fort Rucker, and Fort Hood and verified that all the RCCBs on the four test helicopters inspected were operational. Nine of the RCCBs we tested were from the pilot assembly line.

Design

Remote control circuit breakers are trip-free thermal devices which combine the functions of a conventional circuit breaker and relay into one device. These devices can be employed as circuit breakers that can be mounted adjacent to the load, the power source, or even the flight deck. The RCCBs will open automatically on electric current overloads up to and including short circuit conditions within the operating specifications of the device. The circuit breakers provide thermal/mechanical circuit interruption in the event of an electric current overload. An ancillary thermal-mechanical 0.5 ampere circuit breaker I/CU (located remotely from the RCCB) controls the main contacts in the RCCB. The I/CU also provides a method for manually opening/closing the RCCB under normal operating conditions.

An AH-64A Apache Attack Helicopter contains four RCCBs on the aircraft wings and one behind the pilot seat. A 20-ampere RCCB (behind the pilot seat) is used in the electrical power center which controls armed power for the Hellfire launcher. Two 25-ampere RCCBs are located in each aircraft wing just above each pylon station.

We reviewed TI RCCB schematics (No. 36713-1) and conducted a detailed circuit analysis of the RCCB operation. We observed and verified TI testing of RCCB design and circuitry against the performance characteristics such as voltage, current rating, auxiliary switch, endurance (50,000 cycles), voltage drop, etc. On the basis of our review of the design and test of the RCCBs, we concluded that the RCCB design is sound. Additionally, we observed that despite the fact that the Apache helicopters have been exposed to all kinds of environmental conditions, no significant number of RCCB failures caused by quality or operational performance have been reported.

Summary

The allegation was not substantiated. The quality of the first 719 RCCBs manufactured by Texas Instruments on the pilot line was sound. Our records showed that only about 1 percent of RCCBs system-wide have been issued to the field over the last 10 years. Our field test fault detection and location

Remote Control Circuit Breakers Quality, Testing, and Design

system in the missile subsystem electric circuitry and RCCB pop-up switch BITs at various Army facilities verified that all the RCCBs on the four test helicopters inspected were operational. Our open inspection of an RCCB from the original pilot assembly line was found with no workmanship defects.

Although 719 RCCBs were manufactured on the pilot assembly line approximately 15 years ago, a number of those devices are still functioning well in the field. Thus, we conclude that the design, quality, test, and operability of the RCCBs produced on the pilot assembly line and used on the AH-64A Apache Attack Helicopter Hellfire Missile System are adequate.

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Part II - Additional Information

Appendix A. Evaluation Process

Scope

We conducted this technical assessment from February 1997 through September 1997 in accordance with standards implemented by the Inspector General, DoD. We reviewed data and tested remote control circuit breakers on the AH-64A Apache Attack Helicopter.

Methodology

Our review focused on identifying design, test, operability, and quality assurance processes of the remote control circuit breakers. We developed specific plans for evaluating the implementation and acceptability of the remote control circuit breaker process. We reviewed the remote control circuit breakers functions and operations, procurements, field failures, quality assurance process, serial numbers, and date codes. Technical assessment engineers conducted inspection and pop-up switch testing of remote control circuit breakers on Apache helicopters at Fort Eustis, Fort Rucker, Fort Hood, and Corpus Christi. We did not rely on computer-processed data or statistical sampling procedures to develop conclusions on this evaluation.

Management Control Program

DoD Directive 5010.38, "Management Control Program," August 26, 1996, requires DoD organizations to implement a comprehensive system of management controls that provides reasonable assurance that programs are operating as intended and requires the organizations to evaluate the adequacy of their controls.

Scope of Review of the Management Control Program. We reviewed the adequacy of management controls relating to manufacturing, quality control, testing, and acceptance process to ensure that RCCBs conform to the acceptable final assembly processes.

Adequacy of Management Controls. Management controls utilized to ensure that the manufacturing, quality control, testing, and acceptance of the RCCBs were adequate. We identified no material management control weaknesses.

Contacts During the Evaluation

We visited or contacted individuals and organizations within the DoD and within McDonnell Douglas Helicopter Systems and Texas Instruments, Inc. Further details are available upon request.

Appendix B. Report Distribution

Office of the Secretary of Defense

Under Secretary of Defense for Acquisition and Technology
Deputy Under Secretary of Defense (Acquisition Reform)
Director, Defense Logistics Studies Information Exchange
Under Secretary of Defense (Comptroller)
Assistant Secretary of Defense (Public Affairs)

Department of the Army

Auditor General, Department of the Army

Department of the Navy

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- Senate Committee on Governmental Affairs
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- House Subcommittee on National Security, Committee on Appropriations
- House Committee on Government Reform and Oversight
- House Subcommittee on Government Management, Information, and Technology,
Committee on Government Reform and Oversight
- House Subcommittee on National Security, International Affairs, and Criminal
Justice, Committee on Government Reform and Oversight
- House Committee on National Security

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